Winter Covercrops

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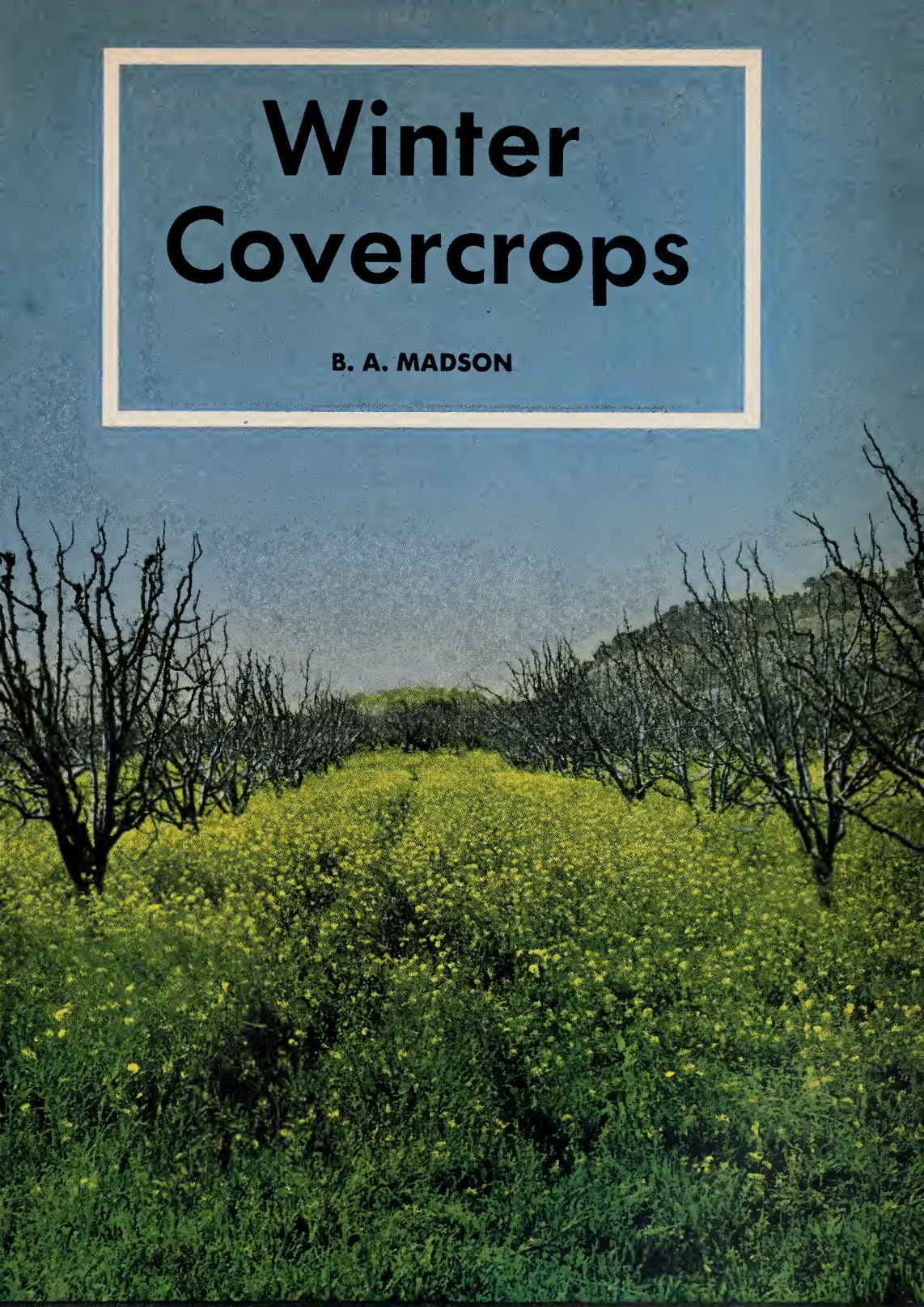

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Why use covercrops?

1. For many farm lands, covercrops offer the only practical means of supplying the organic matter necessary to keep soil in a high state of productivity.
2. This organic matter makes the soil more friable, improves its tilth, and facilitates water penetration.
3. As the organic matter decays, it can provide soil nutrients such as nitrogen for succeeding crops.
4. If the cover crop is a legume, it will increase the nitrogen content of the soil.

This circular tells you

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This covercrop of mustard will supply the orchard with vital organic material.

How a covercrop helps the soil . . Page 4
How to select a covercrop 9
How to grow a covercrop 18
How to work in a covercrop 22

A CHART COMPARING CHARACTERISTICS OF COVERCROPS ADAPTED TO CALIFORNIA WILL BE FOUND ON PAGE 12

How a covercrop helps the soil

IT IS A GENERALLY accepted fact that the periodic addition of organic matter is advantageous—if not absolutely necessary—in order to keep our soils in the highest state of productivity. On many soils good yields can be maintained by the use of commercial fertilizers, but it is a common observation that increases in yield following liberal application of organic matter are often greater than can be accounted for by the plant food elements which the organic matter contains.

The soil organic matter consists largely of plant roots and other residues in various stages of decomposition. When a plant dies, or when plant material is mixed with the soil, decomposition sets in rapidly if moisture and temperature conditions are favorable. This material soon loses its original identity and cellular structure, leaving a black, structureless residue, correctly referred to as humus.

The two most important factors in determining the rate of this decomposition are moisture and temperature. High moisture and high temperature are particularly favorable for the activity of the micro-organisms of the soil, and hence favor a rapid rate of decay.

The character of the organic matter added also influences the rate of decomposition. Green succulent material, such as mustard, which is high in nitrogen and rich in sugars, starches, and other materials readily available as food for the soil organisms, decays rapidly. Dry material such as mature grass or grain straw, which is low in nitrogen and other available food constituents and high in structural substance, decays much more slowly. In either case, the resulting humus, which is the result of the interaction of the soil organisms and the more resistant plant material, appears to have about the same composition regardless of the original plant material. While further decomposition of the humus material will continue, it is at a much slower rate than that of fresh organic matter.

Cultivation decreases organic material

The organic matter content of virgin soils varies greatly, depending on the amount and character of the natural vegetative cover and the rate of decomposition. In any locality the organic matter content of a virgin soil is relatively static, representing a balance between the annual addition and the rate of decomposition. When land is brought under cultivation, this balance is disturbed, with a resulting decrease in organic matter.

The principal reason for this decrease is that cultivation creates conditions favorable for more rapid decomposition. This is particularly true on irrigated land where the soil is kept moist throughout the warmer part of the year, which greatly favors bacterial action. Theoretically, with any system of farming a balance will be restored ultimately between the annual addition to the soil of crop residues and the rate of decomposition, but with an organic matter content considerably below that of the virgin soil. Before such a balance has been obtained, however, production will usually have declined to such a point that a program of soil improvement is necessary to maintain profitable yields. In any event it will not be possible in most cases to maintain the organic matter content in the soil at its original level, nor does this appear to be necessary.

Organic matter improves soil

Organic matter benefits the soil in a number of ways. First, it improves the physical condition of the soil by making it more friable, improving its tilth, and facilitating water penetration. Soils with a large amount of organic matter are nearly always in better physical condition than soils with a low organic matter content. As the organic matter decreases, the soil becomes less friable and more inclined to puddle and run together, and the rate of water penetration is decreased. There is some evidence to indicate that it is not so much the amount of organic matter as it is the condition of the organic matter that is important. Organic matter in a rapid process of decay exerts a very strong influence on the physical condition of the soil even though the humus residue that remains may be exceedingly small.

At the Imperial Valley Field Station, for example, the soil is heavy and of exceedingly poor tilth. On certain areas a covercrop has been grown each year for the past 10 years. Under the prevailing conditions of high temperature and moisture, the rate of decay of this succulent material has been very rapid and so complete that no increase in the organic residue can be detected. Nevertheless the effect on the physical condition of the soil, as well as its productivity, has been very marked. The tilth and friability of the soil, as well as water penetration, have been greatly improved. Further, when the addition of organic matter is discontinued for a few years the soil soon returns to its original unfavorable state.

It would appear that fresh organic matter in a process of rapid decay is more effective in the improvement of the physical condition than is the humus residue.

It appears probable that this improved tilth may be due to the soil organisms which multiply rapidly as a result of the increased food supply when organic matter is added. Martin and Waksman[1] contend that the fungus micellia tends to bind the soil particles together in bundles, while Peele[2] has shown that bacteria secrete gums which cement soil particles into larger aggregates.

This would also explain why the soil again loses its tilth soon after decomposition of the organic matter has been effected. The food supply having been decreased, the soil organisms die off, and the fungus micellia and bacterial gums, being organic in nature, also decay and disappear.

Organic matter increases plant nutrients

Another possible effect of organic matter is to increase the available plant nutrients in the soil. As the organic matter decays, the nutrient elements which it contains are liberated and may become available to succeeding crops.

The availability of plant nutrients is influenced to some extent by the composition of the organic material added. If material such as grain straw is added to the soil, it may exert a marked depression on the succeeding crop. This is due to the fact that straw is low in nitrogen, containing normally not more than .5 to .8 of one per cent, but rich in other food material. As a result of this high food supply, the soil organisms multiply rapidly. Since the organisms cannot secure all the nitrogen they need from the straw, they draw their supply from other sources, particularly the nitrates which would normally be available for the succeeding crop. In effect, they are competing with the crop for available nitrogen with detriment to the latter. This effect, however, is temporary. When the straw has decayed to the point where most of the readily available energy material has been used up, the activity of the soil or-

[1] Martin, J. P., and Waksman, S. A. Influence of micro-organisms on soil aggregation and erosion. Soil Science 50:29–47. 1940.

[2] Peele, T. C. Microbal activity in relation to soil aggregation. Jour. Amer. Soc. of Agron. 32: 204–212. 1940.

ganisms decreases and the nitrates again accumulate in the soil.

When material high in nitrogen (2 per cent or more) is added to the soil, there is no such depressing effect on the succeeding crop. Such material contains all the nitrogen needed by the organisms, so that they do not use up the already available nitrates. Legumes normally contain more than 2 per cent of nitrogen, as do most nonleguminous plants at the stage of growth at which they are worked into the soil as green manure crops. No depressing effect is normally obtained when a covercrop is worked in, whether it be a legume or nonlegume. At least the effect, if any, is so temporary as to be of little concern.

If the source of the organic matter is a legume, such as alfalfa or clover (which may be used in the rotation), or a leguminous covercrop such as peas or horse beans, there may be substantial increase in the nitrogen content of the soil. Such sources of organic matter, however, do not increase the mineral supply but simply serve to make some of the minerals more readily available. On soils deficient in mineral nutrients such as phosphorus or potash and the like, these elements must be supplied in the form of commercial fertilizer.

In addition to improving the physical condition of the soil and making available a quantity of nutrient elements, the application of organic matter appears to exert other favorable influences, as yet not clearly understood. As measured by the yield of the succeeding crop, the results in many cases are greatly in excess of those which can be attributed to the elements of fertility which the material contained. It is well known that the addition to the soil of a quantity of readily decomposable organic matter greatly stimulates the activity of many of the soil organisms. It is quite possible that this activity results in the synthesis or liberation of a growth-promoting substance stimulating to plant growth.

At any rate it is well recognized that in order to maintain soils in the highest state of productivity provision must be made for the systematic addition of organic matter as a regular part of the farming program. The definitely established benefits are sufficient justification for the practice.

How to add organic matter

Organic matter may be added to the soil in three ways:

1. Through crop residues.
2. By the application of manure or other organic materials such as composts.
3. By the use of green manure crops.

In practically all systems of farming some organic matter is continually being added to the soil from crop residues or weeds and other volunteer growth. The amount varies greatly, however, depending on the type of farming and the kind of crops grown.

In a general type of farming where annual and perennial crops are grown in a systematic rotation, and especially where such sod crops as alfalfa or clover are used in a rotation of relatively short duration, sufficient organic matter may be added to the soil to maintain it in good condition.

In California, however, there are many types of farming in which definite soil building rotations are not used or are not feasible. Particularly is this true in orchards and in areas where such specialized crops as sugar beets, tomatoes, and others are grown. Even on our nonirrigated grain land the additions to the soil in the form of crop residues, while important, are insufficient to keep the soil in good physical condition or in the highest state of productivity.

Barnyard manures and other organic manures, while important, are wholly inadequate to meet the requirements of the extensive areas on which organic matter is needed. For a considerable portion of our farm lands, therefore, covercrops

Use of legumes such as alfalfa (above) as covercrops may increase substantially nitrogen content of the soil.

offer the only practical means of supplying the organic matter necessary in the quantity required to keep the soil in proper physical condition or in a high state of productivity.

The value of covercrops has been proved

The use of covercrops in California agriculture is not new. They have been used for more than 50 years, particularly in orchards. In recent years, due to the stimulus of high prices and the urge for maximum production their use has increased. However, there are still many other areas in which their use could be employed with profit.

Unfortunately, no statistics are available on the acreage planted to covercrops each year, but conservative estimates indicate that it is in excess of 500,000 acres. On a portion of this area—probably considerably less than 25 per cent—volunteer covercrops are used. These consist of volunteer growth and weeds which are allowed to grow during the winter and are then worked in during the spring. The remainder consists of crops seeded for the purpose of soil improvement.

Measured in terms of the yield of succeeding crops, the effect of a covercrop naturally varies with the physical characteristics of the soil and its natural productivity. It also varies with climatic conditions, the kind of covercrops, and the total growth obtained. On many farms where covercrops could be employed to advantage, farmers have failed to use them because they have not been satisfied with the results. Failure to secure desired results can be attributed in many instances to use of the wrong crop for the locality or failure to use proper cultural methods.

Long term experiments adequate to answer all the questions involved have not been conducted, but short term trials have been carried on from time to time during the past 40 years. The results of some of these trials have been phenomenal.

In 1912, Shaw[3] reported the results of covercrops preceding wheat on a sandy soil at Ceres, California. Wheat after fallow yielded 33 bushels per acre, while wheat following a covercrop of rye and vetch yielded 52 bushels per acre. In similar tests conducted on more fertile soils at Davis some increase in yield was obtained, but the results were less striking than those at Ceres.

In 1918, Mertz[4] reported the results of several years work with covercrops at Riverside. In this test the covercrop plots produced a 40 to 50 per cent higher yield of corn, potatoes, cabbage and sugar beets than did the plots on which no covercrops were grown. Of further interest was the fact that the plots on which leguminous covercrops were grown produced substantially higher yields than did the non-legume + nitrogen fertilized plots. The total nitrogen available was approximately the same in both cases.

In a test conducted by the California Agricultural Extension Service in Ventura county the introduction of a sour clover, *Melilotus indica*, covercrop in the usual sugar beet–lima bean rotation resulted in substantial increases in yield of both the sugar beets and the beans. Numerous trials by farmers in various sections of the state have in many cases given equally striking results.

[3] Shaw, G. W. How to increase the yield of wheat in California. Calif. Bull. 211, 1912.

[4] Mertz, W. M. Green manure crops in southern California. Calif. Bull. 292, 1918.

Organic matter added to the soil by volunteer growth (above) is rarely sufficient to maintain productivity.

How to select a covercrop

Covercrops may be grown either during the winter or summer. Most of the acreage in California, however, is cropped to winter growing species. The reason for this preference is twofold:

1. Winter crops can be grown more cheaply since they normally require but little irrigation.

2. Winter crops fit into most farming practices better than do summer crops and interfere less with other farm operations. Only those species suitable for use as winter growing crops will be discussed in this circular.

There are a large number of varieties and species of plants which can be grown as winter covercrops in California. Most of these are legumes, though some nonlegumes—particularly the mustards—are important in some sections. The value of a covercrop is determined primarily by the amount of organic matter it will add to the soil. Therefore, use the crop which will produce the greatest growth in any particular region or in the time allotted.

Other things being equal a legume is better than a nonlegume since it will add to the nitrogen content of the soil. In fact, a good growth of well-inoculated legume will frequently add as much nitrogen as several hundred pounds of high grade nitrogen fertilizer.

The characteristics of the soil and the effect desired also determine to some extent the kind of covercrop to be used. On the lighter sandy soils, the fine-stemmed, more succulent species will usually produce the best results. On the heavy, fine-textured soils, such as clay-loam and adobe, a covercrop producing a stemmy growth with a well-developed taproot will usually loosen up the soil more effectively and have a more beneficial effect on the physical condition. In recent years many orchardists have changed from vetch to mustard since they find that the latter, with its well-developed deep penetrating taproot, is more effective in loosening up the soil and encouraging water penetration, which is one of the major problems in many orchard areas.

The fine-stemmed species used as covercrops include most of the vetches and vetchlike species, peas, bur clover, and cereals. The coarser-stemmed group includes fenugreek, melilotus, horse bean, and the mustards.

Of the large number of species adapted to California conditions relatively few make up the major portion of the seeded covercrop acreage. A number of very promising species are rarely used because of the scarcity or high price of the seed. The more promising of the little-used species will be discussed in this circular since seed supplies could and doubtless will be made available whenever the demand justifies.

Legumes adapted to California

THE VETCHES

With the exception of the horse bean and the bitter vetch, all the species of vetch which can be grown in California are slender, viny plants. As a rule they do best if sown with some oats or other erect plants for support.

Except for some areas along the coast, most vetch covercrops are grown on irrigated land. To assure a good stand the crop must be seeded in the fall before the soil gets cold, which means that preirrigation is necesary. If seeding is delayed until after the first fall rain, which may not come until November or Decem-

ber, the soil is often so cold that the stand will be poor and the results disappointing. This is particularly true in the Central Valley. Along the coast, winter temperatures are more moderate and seldom become too cold for germination.

The most distinguishing feature of the vetches is that the leaves are compound, made up of several pairs of leaflets, but without a terminal leaflet. In place of the latter, the midrib in most species terminates in a tendril which enables the vetch to cling to other erect growing plants.

The species which are grown or which have shown promise in some sections of California are:

Purple vetch	*Vicia atropurpurea*
Common vetch	*Vicia sativa*
Hairy vetch	*Vicia villosa*
Calcarata vetch	*Vicia calcarata*
Monantha vetch	*Vicia monantha*
Hungarian vetch	*Vicia pannonica*
Bitter vetch	*Vicia ervilia*
Horse beans	*Vicia faba*

Purple vetch. This is a vigorous viny species, the whole herbage being markedly hairy or pubescent. It produces a compact raceme or cluster of purple flowers, borne on a long stem or peduncle arising from the axis of the leaf. The seeds are quite distinctive, being unusually velvety black with a white hilum or eye.

Purple vetch first came into prominence as a covercrop in the middle twenties. Owing to its superior performance and wide adaptation it rapidly increased in popularity and soon become the most important covercrop species in most agricultural areas of the state.

Purple vetch does well in all sections where the winter temperatures do not fall too low. It has successfully withstood temperatures of 20° F, but prolonged periods of cold weather at or near this point are likely to prove injurious.

At Davis, when harvested at its maximum growth, purple vetch has produced yields of 12 to 15 tons of green matter per acre. In the Imperial Valley yields of well over 20 tons have been recorded. When used as a covercrop, the plants seldom attain their maximum growth before being plowed under. However, because this species usually makes more growth during the winter and early spring than most vetches, the yield is normally proportionately greater than can be obtained from the other species. Another advantage of purple vetch over the common vetch, its chief competitor, is its more consistent performance. This is especially true along the coast and in the Central Valley.

Seed production of purple vetch in California has kept pace with demand. Seed production has increased from 4,000,000 pounds in 1939 to 11,600,000 in 1946. A considerable portion of this has been used for the production of hay, but an increasing amount has also been needed to meet the covercrop requirements. Unfortunately, no data are available on the relative amount used for each of these purposes.

Common vetch. This species is also known as spring vetch and Oregon vetch. It is quite variable but the strains commonly grown are similar in growth habit to purple vetch. The herbage is usually smooth or with but little pubescence or down. The flowers are quite large, blue or bluish purple or bicolored, and are borne without a stem in the axis of the leaf. Only a few flowers are present in each raceme.

At one time common vetch was the most important covercrop species. It still is important, but in many sections has been largely replaced by purple vetch. It is adapted to about the same conditions as purple vetch and is slightly more cold resistant, but as a rule it will not make as much growth during the winter or as much total growth as will the latter.

In recent years an Oregon selection known as Willamette vetch has been grown to a limited extent. It is reported

to be more cold resistant than the common strain, but appears to have no particular advantage for California conditions.

With the exception of the coastal areas, common vetch should be seeded on preirrigated land not later than November 1st in order to assure a good stand.

Hairy vetch. This species is also known as sand vetch and, as the name implies, is better adapted to sandy soils than most other species.

Hairy vetch produces a rather coarse viny growth. The herbage including the leaves and stem is quite hairy, though smooth strains also exist. The flowers are blue and are borne in rather loose racemes, the whole flowering being borne on long stems or peduncles.

Unlike the other vetches hairy vetch is extremely winter hardy. At higher elevations where winter temperatures are low, if seeded early enough to become established before the ground freezes, it will remain dormant during the winter and renew growth when the soil thaws out in the spring.

Even in the valleys where winters are not severe, hairy vetch goes dormant, with the result that little or no growth is made until spring. For this reason it is not satisfactory where the covercrop must be plowed under early. If it can be permitted to make its full growth or to remain as late as early May, it will frequently outyield other varieties. Another deterrent to its use is the high price of the seed, which is usually two or three times that of common or purple vetch.

Calcarata vetch. This is a fine-stemmed viny species, smooth, and light green in color. The flowers are pink, turning blue with age, with only a few flowers in a raceme, which is borne on a long peduncle.

Calcarata vetch is grown to a limited extent in the Imperial Valley, where it has shown great promise. It is also possible that it would be of value in some of the coastal areas, but it has not been tested sufficiently to warrant a definite recommendation. Seed supplies are still scarce. It is less winter-hardy than common or purple vetch, and has not proved satisfactory for use in the Sacramento or San Joaquin valleys.

In the Imperial Valley it may be planted earlier than the other varieties. It may be planted as early as September 1st, and should not be planted later than October 20th. It makes a rapid vigorous growth and is usually ready to plow under in 90 to 100 days, whereas purple vetch requires 120 to 150 days to make its best growth. Calcarata vetch, therefore, is particularly valuable where the covercrop must be plowed under early in preparation for spring planting.

In the Sacramento and San Joaquin valleys there has been some interest in finding a covercrop which can be grown during the late summer and fall and be ready to plow under in the early winter, especially in the preparation of land for sugar beets and similar crops. Summer legumes, because of their susceptibility to early frosts and their slow growth during the short days of the fall, have not proved satisfactory. Tests with various winter legumes planted during the summer have indicated that calcarata may be quite valuable in filling this need. While most winter legumes do not germinate readily during the warmer months, excellent stands of calcarata vetch have been obtained when planted during August or September. By early December the calcarata vetch had made its maximum growth and produced a yield which compared favorably with the yields normally obtained from winter grown crops.

The following data are the results of tests conducted at Davis in 1938 and 1939:

		Yield of dry matter in tons per acre	
Date planted	Date cut:	12-15-38	1-13-39
August 12, 1938		.955	.87
August 22, 1938		1.06	1.13
September 2, 1938		1.23	1.15
September 15, 1938		1.21	1.06

CHARACTERISTICS OF COVERCROPS ADAPTED TO CALIFORNIA

Crop	Density of growth	Soil	Type of growth	Cost of seed	Time to plant	Resistance to cold
			Legumes			
Common vetch	Moderate	Loam	Succulent	Moderate	October November	Moderate
Purple vetch	Moderate to heavy	Loam	Succulent	Moderate to low	October November	Moderate
Hairy vetch	Moderate to heavy	Sand loam	Succulent	High	October November	Resistant
Calcarata vetch	Moderate	Loam to heavy	Succulent	High	October November	Intolerant
Monantha vetch	Moderate	Loam to heavy	Succulent	Moderate to low	October November	Moderate
Hungarian vetch	Moderate	Loam to heavy	Succulent	Moderate to low	October November	Moderate
Bitter vetch	Moderate	Loam to heavy	Stemmy	High	October December	Moderate
Horse beans	Moderate to heavy	Loam to heavy	Stemmy	High	October November	Moderate
Tangier peas	Heavy	Loam to heavy	Succulent	High	October November	Moderate

Wedge peas	Light	Loam to heavy	Succulent	High	October December	Moderate
Field peas (Canada)	Moderate	Loam to heavy	Succulent	Moderate	October November	Moderate
Field peas (Aus. winter)	Moderate	Loam to heavy	Succulent	Moderate	October November	Resistant
Melilotus indica	Moderate	Loam to heavy	Stemmy	Low	October November	Moderate
Melilotus alba	Light to moderate	Loam to heavy	Stemmy	Low	October November	Resistant
Fenugreek	Light	Loam to heavy	Stemmy	Moderate	October January	Moderate
Bur clover	Light	Loam	Succulent	Moderate	October November	Moderate
			Nonlegumes			
Mustards	Heavy	Loam to heavy	Stemmy	Moderate	October November	Moderate
Wheat	Moderate	Loam to heavy	Succulent	Moderate	October January	Moderate
Barley	Moderate to heavy	Loam to heavy	Succulent	Moderate	October January	Moderate
Oats	Moderate to heavy	Loam to heavy	Succulent	Moderate	October January	Moderate
Rye	Moderate to heavy	Sandy to heavy	Succulent	Moderate	October January	Moderate

A similar test made in 1939 gave the following results:

Date planted	Yield of dry matter in tons per acre Date cut: 12-15-39
August 10, 1939	2.28
August 28, 1939	1.74
September 5, 1939	.93
September 22, 1939	.36

The variation in yield reflects to some extent the difference in stand obtained but the results indicate that a very satisfactory covercrop can be produced by this species if planted in August or early September.

Monantha vetch. This is somewhat similar in appearance to the calcarata vetch, possessing small leaflets and bearing a few blue to purple flowers in each raceme. It is adapted to about the same conditions as common vetch. Some years ago there was considerable interest in this species, but its performance one year with another proved to be inferior to either purple or common vetch. At present it is used but little, and on the basis of present knowledge there seems no reason for recommending its use.

Hungarian vetch. This species resembles the common vetch in its habit of growth but the whole plant is very hairy; the flowers are creamy white and borne mostly in dense axillary racemes. It is more tolerant of low temperature and wet conditions than is common vetch, but ordinarily will not produce as large a growth as the latter. This species has not been commercially used in California and, in fact, has been used very little in this country. It is occasionally found as a mixture in common vetch seed obtained from Oregon.

Bitter vetch. This species differs from the other vetches in being bushy instead of viny, and is without tendrils. The stems are rather fine, and leaflets are small and numerous. The flowers are small, white or bluish in color, and borne on long peduncles. The pods are short and rounded, the seed angular.

Bitter vetch has been used but little as a covercrop, but it deserves more attention. It produces a dense bushy growth, attaining a height of 12 to 18 inches. It is easier to obtain a stand with this species than with most vetches, and in tests throughout the state it has shown but little tendency to be injured by cold weather. It is a prolific producer of seed which does not shatter readily, making possible cheap production. As the name implies the herbage is rather bitter and, therefore, of little value as forage.

Horse bean. While the horse bean is a vetch, it differs markedly from the other species discussed in its habit of growth. It is a coarse, erect, stemmy plant with a large taproot, and quite large leaflets. The flower is white with a black spot on each wing and is borne in sessile axillary racemes. The seeds are large.

In the common variety known as broad or Windsor bean the seed is flat and about 1 inch long by ¾ inch broad. In the small seeded varieties the seeds are more rounded, and range from ⅜ inch to more than ½ inch in diameter.

The horse bean is adapted to about the same conditions as common and purple vetch. It is, however, more susceptible to low temperature and other adverse climatic conditions and in many areas is not as dependable in performance. It is also quite susceptible to the attack of black aphis, which seldom affects its use as a covercrop but often interferes with the production of seed.

Because of its large taproot and stemmy growth, the horse bean is an excellent covercrop for opening up heavy soils. It is grown mainly in the central coast areas and to a limited extent in the Sacramento and San Joaquin valleys. It is far less important, however, than the purple and common vetch. The principal deterrent to its use is the high cost of the seed.

MISCELLANEOUS LEGUMES

In addition to the vetches there are a number of other legumes which are used as covercrops or which show considerable promise for that purpose. Some are quite similar to the vetches in their growth habit, such as the peas and the vetchlike species belonging to the genus *Lathyrus*. Others which differ materially in their growth characteristics are melilotus, fenugreek, and bur clover.

Field peas (*Pisum sativum*). Field peas belong to the same species as garden peas and, in general, their growth characteristics are identical with the latter. Garden peas as a rule have white flowers, while many of the field peas have colored flowers. There are a great many varieties of field peas known which vary greatly in time of maturity, total vegetative growth and other characteristics. Unfortunately, very little work has been done with field peas in California, and practically nothing is known regarding the relative merits of the different varieties.

Field peas are being used to some extent for soil improvement purposes, but for various reasons have never become very popular. The principal reason probably is the large amount of seed required to plant an acre which, with the relatively high price, makes the cost of seeding expensive.

The most common varieties of field peas used in California are the Canada white, the Canada yellow, and the Austrian winter and its derivatives. The two former varieties are adapted to the same conditions as purple vetch, being particularly partial to loam soils. They must be planted early in order to become well established before the cold weather of the winter sets in. Under favorable conditions these varieties will usually produce a good growth; they will rarely produce as heavy a tonnage as purple vetch.

The Austrian winter pea is a large vigorous growing type adapted to a wide range of soil conditions. Like hairy vetch it is a cold-resistant variety and goes dormant during the winter. It does not make an appreciable growth until late in the spring—too late to be of much value as a covercrop. If it can be permitted to grow until late May, it will usually produce as large a growth as most other legumes. The Austrian winter pea has smaller leaflets than the nonhardy varieties and colored flowers.

A considerable acreage of the Austrian winter pea has been grown in California for seed, for which there has been some demand in the southern states.

Two strains, the early Austrian and the Dixie wonder, are selections of the Austrian winter and differ from the latter only in that they mature earlier.

Vetchlike plants (*Lathyrus* sp.). Several species of *Lathyrus* which have growth characteristics similar to the vetches have been used in a limited way. For one reason or another they have never been able to compete with the vetches for covercrop purposes. The best known of these species is the Tangier pea, *Lathyrus tingitanus*, a vigorous growing, viny plant with large showy red flowers similar to the sweet pea to which it is closely related.

It is adapted to the same conditions as the common and purple vetch. Experimentally it has given good results on a wide range of soil types. In most areas where tried the growth produced has compared favorably with other legumes.

Its main disadvantages are that it is rather a shy seeder and the seed is large, requiring the use of 75 to 100 pounds per acre. These factors have made the cost of seed prohibitive.

Wedge pea. Another species of *Lathyrus*, the wedge pea, *Lathyrus sativus*, has been exploited to a limited extent. It is a low growing, viny plant, with long narrow leaflets, large white to blue flowers, and rather large angular seeds which may vary from gray to white in color. In numerous tests throughout the state it has seldom produced as heavy a tonnage as the vetches. The seed is large

When a mustard is used as a covercrop (above), nitrogen fertilizer is usually added at time of seeding.

and expensive. Its only virtue as compared with most winter legumes is that the germination of the seed is less affected by low temperatures. A fair stand can usually be obtained even though planted late in the fall or early winter.

Rough pea (*Lathyrus hirsutus*). The interest in this species stems mainly from its use in the southern states as a winter covercrop. It is a succulent, viny legume, similar to the vetches in its habit of growth. It has not shown any particular promise in California as it grows rather slowly and matures late. It is a fairly prolific producer of seed, which may possibly be grown with profit for sale out-of-state.

Melilotus. There are several species of melilotus, but the most important as a covercrop is sour clover, *Melilotus indica.* This is an erect stemmy plant similar in its habit of growth to other sweet clovers. It is an annual with small yellow flowers borne in short dense racemes. It varies in height from a few inches to several feet depending on environment.

It has a good taproot and is valuable for opening up heavy soils. It is of greatest value from central California south. In the northern half of the state the winters are too cold for a satisfactory growth. It has been used extensively in southern California, particularly in orchards. Its chief virtue is that the seed is abundant, cheap, and easy to grow where adapted.

The other species of sweet clover, such as the annual white-flowered form known as hubam, *Melilotus alba,* are used but little as their growth comes too late in the spring to fit into the usual covercrop program. Where they can be used in a short rotation program they are excellent for opening up heavy soils.

Fenugreek (*Trigonella foenum-graecum*). It is an annual legume closely related to and similar in its growth habit to melilotus. It seldom attains a height of more than 2 feet. Its flowers are sessile, with few flowers in each raceme. The flowers are white with blue marking. The pods are long, slender, and almost round in cross section. The seeds are yellow to brown and angular in shape. The herbage has a strong aromatic odor.

Fenugreek is excellent for opening up heavy soils. However, it seldom makes as heavy a growth as some of the other legumes where the conditions are favorable for the latter species.

Its chief virtue is its ability to germinate in low temperatures, which permits it to be seeded later in the fall than such legumes as vetches and peas. It is one of the few legumes which can be seeded as late as December with a fair degree of assurance of securing a good stand. This makes it usable on unirrigated land as well as on irrigable land.

At present it is used to a limited extent in the Sacramento Valley in rotation with beets or tomatoes, but it may assume greater importance as covercrops become more necessary on unirrigated lands. In the southern part of the state, where winters are mild enough to permit late planting of such legumes as peas and vetches, fenugreek is never likely to become popular. In such areas the other legumes will normally produce a heavier growth.

Bur clover (*Medicago hispida*). This is one of the most common and widespread legumes in California and has been used to a considerable extent as a covercrop. While it has been seeded to some extent, its greatest value has been as a volunteer covercrop. Its prevalence in grain fields has doubtless contributed greatly to the continued productivity of these areas.

Bur clover will not normally produce as heavy a growth as will some legumes, and the prevailing high price of seed will also limit its use.

Nonlegumes adapted to California

Any plant which will make good growth in the time available may be used as a covercrop and a number of nonlegumes are used in this way. The most important are mustards and cereals.

These crops do not add nitrogen to the soil but, where improvement of the physical conditions of the soil is most important, their large vegetative growth will often offset the lack of nitrogen addition.

Mustards. Any species of mustard may be used of which seed is available. The most common perhaps is a form of black mustard, *Brassica nigra*, known locally as Trieste. A brown seed species, *Brassica juncea*, is also used. Most of the mustards available, however, are a mixture of types and species. Unfortunately, practically no effort has been made to determine the relative merits of the various types and species.

Mustards are used as covercrops mainly in orchards and similar situations. It is common practice to apply a liberal application of nitrogen fertilizer at the time of seeding. The nitrogen not only stimulates the growth of the mustard but also counteracts the competition with the trees for nitrogen. The nitrogen taken up by the covercrop will, of course, become available to the trees as the organic matter decays.

The mustards are not used in general farming or in rotation with annual crops. Most, if not all, the species contain some hard seed which will remain dormant in the soil and appear as a weed in the succeeding crop.

Cereals. While these are not as effective in increasing water penetration as legumes or mustards, they do improve the tilth of the surface soil and stimulate the growth of some succeeding crops. Their chief advantage is that they can often be grown where other types of covercrops have not proved satisfactory. They are easy to get started, even during cold, unfavorable weather, and the seed is relatively cheap and abundant. They will usually make more growth during the winter months than most plants.

While any of the cereals may be used, rye and barley are most commonly employed. Rye is commonly used on poor soils or on sandy or rocky soils. On such soils it will normally produce a better growth than the other species. Only the spring types of rye should be used. Since rye does not tiller heavily, a high rate of seeding should be used.

Barley, on the other hand, will make a quicker and heavier growth in a shorter time than the other cereals and is often used in preparation for crops that must be planted early in the spring.

While no data are available on the subject, the practice of plowing under a heavy growth of volunteer grain in the spring, especially on our nonirrigated land, may be an important factor in maintaining the productivity of such areas.

How to grow a covercrop

The value of a covercrop largely depends upon the growth which it will make and the dry matter produced during its growth period. It is important, therefore, to provide conditions as favorable for growth as possible. The factors to be considered are:

1. The preparation of the seedbed.
2. The time of planting.
3. The rate of seeding.

Preparation of the seedbed

This is important. Just as good a seedbed should be prepared as for a similar commercial crop. For small seed crops like melilotus, bur clover, and mustard, a firm seedbed—well-supplied with moisture close to the surface—should be provided. A seedbed considered satisfactory for alfalfa will also be satisfactory for such small seeded crops.

For the larger seeded crops like vetches and peas, which can be planted deeper, a more loose and open seedbed may be satisfactory. However, to assure prompt germination it is necessary that the soil be firm and moist at the depth to which the seed is planted. The seedbed for this latter group should be about the same as that which would be prepared for milo or beans. Germination and establishment of the crop should be as quick as possible.

Fertilizers. While no general fertilization program can be recommended, it is increasingly evident that many soils are deficient in one or more elements needed for plant growth. For legumes the most common deficiency is of sulfur and phosphorus. Conrad[5] *et al.* has shown that on some of our dry-farmed grain lands applications of sulfur, either in the form of gypsum or elemental sulfur, will greatly stimulate the growth of bur clover and other resident legumes. This, in turn, will have a strikingly beneficial effect on the following grain crop. Similar results have been obtained with phosphorus in areas where this element is deficient. In many of the irrigated areas vetches and other legumes will show a marked response to similar treatments.

Nonlegumes will usually respond to nitrogen and, as has been indicated, the use of nitrogen fertilizer to stimulate growth of mustard is a common practice in some orchard areas.

Our soils, however, vary so greatly in their fertilizer needs that, unless the farmer knows from past experience that certain elements are needed, he should consult his local Farm Advisor.

Inoculation. Most farmers know that legumes will not make their best growth unless well supplied with nitrogen-fixing bacteria, whose presence is indicated by the occurrence of nodules on the plant roots. These organisms have the ability to use the nitrogen of the air and supply it to the plant for use in its growth. Legumes planted on soil low in available nitrogen will usually make a normal, healthy growth if well inoculated with nitrogen-fixing organisms. If these organisms are absent the growth will be very poor, and the crop may even be a complete failure.

These nodule-forming organisms are not normally present in the soil, and if a specific legume is planted on the land for the first time the organism must be supplied artificially. If the same legume is grown on the land at short intervals for several years the population of these

[5] Conrad, John P., Hall, H. L. and Chaugule, B. A. Sulfur fertilization of legumes in the Upper Ojai Valley, California, and the resulting effects on the following non-legumes. Soil Science Soc. of America, Proceedings Vol. 12, pp. 275–277, 1947.

legume bacteria will build up in the soil to that necessary for the maximum growth of the species. It has frequently been observed, for example, that when vetch is planted on a piece of land for the first time, even though inoculated, the growth of the first year will be only fair. If, however, it is planted the second or third year, the growth will be much more luxuriant, since the organisms have increased to the point where they are able to supply the maximum needs of the plant. If the same legume is used year after year on the same land it is usually necessary to inoculate only the initial planting.

The same strain of the organism will not grow on or produce nodules on all legumes. Each species or group of species requires a specific strain. The same strain of bacteria will inoculate alfalfa, bur clover, sweet clover, and fenugreek, but will not grow on the true clover or on vetches, peas, or lathyrus. It is important, therefore, to secure a strain of the bacteria specific to the species to be planted.

While there are several methods for inoculating legume seed, the most satisfactory is to use commercial cultures, prepared by a reputable laboratory. Many seed firms selling legume seed also sell cultures. In using commercial cultures the directions of the manufacturer should be followed. In any case, a few precautions should be taken. The legume bacteria are quite sensitive to high temperatures, to sunlight, and to drying conditions. Do not purchase the cultures very long before they are to be used, for—unless stored under favorable conditions—they may deteriorate greatly before being applied to the seed. Never inoculate in direct sunlight nor more than two days before the seed is to be planted.

The best way to plant inoculated seed is to drill it in as soon as dry enough to handle. If broadcasting is necessary, the seed should be covered with a harrow immediately afterward to prevent the destruction of the bacteria by drying or by direct exposure to sunlight.

Time of planting

The most important single factor in determining the success or failure of a winter covercrop is the time of planting. As indicated earlier, the seed of most of the species used for winter covercrops require a moderately high soil temperature for germination. If the planting is delayed until the soil becomes cold, much of the seed may rot, and the stand will be poor. In the Sacramento and San Joaquin valleys, for example, failure often occurs with plantings made after the middle of November. In these areas the crop should be seeded before the first of November, preferably before the middle of October.

Along the coast from San Francisco south and in southern California the soils as a rule do not get cold as early as they do in the Central Valley; a good stand can usually be obtained even though planting is delayed until later in the season. Even in these areas better results normally will be obtained if planting is done by early December.

In addition to fostering prompt germination and a good stand, another advantage of early planting is that the plants will have an opportunity to make an appreciable growth and become well rooted while the weather is still warm. They will, therefore, be better able to take advantage of an occasional favorable period during the winter, and a heavier tonnage will be obtained by the time they must be worked into the soil in the spring.

As already stated, species vary in their ability to germinate at low temperatures. Fenugreek, the cereals, wedge peas, and bitter vetch will germinate in colder soil than will other species. However, even these crops will make a much better growth if they can be started early and provided with a longer period of favorable growth conditions. Late-planted covercrops may be only a few inches high at the time of turning under and have insufficient growth to cover the ground. It is extremely questionable if the growth

obtained in such cases is sufficient to justify the labor and expense involved.

Most of the covercrops grown in California are planted on irrigated land, which makes it possible to provide artificially the moisture necessary to start the crop at the most favorable time.

On unirrigated land germination obviously is dependent upon the advent of fall rains. If rain comes early and in sufficient quantity to germinate the seed and maintain growth, a good covercrop may be obtained. If the rain does not come until late November or December, poor results are probable. The production of covercrops on dry land, therefore, is far more of a gamble than on irrigable land.

The growing need for the addition of organic matter to such land is attested by the rather startling results of limited trials where a good covercrop has been obtained. Most unirrigated lands are cropped to small grains, and abundant growth of bur clover during favorable years has unquestionably been an important factor in maintaining production on such lands.

The increasing use of herbicides to eliminate weeds is rapidly eliminating bur clover and other legumes from areas on which they were once abundant. This situation can result in an accelerated decrease in the fertility of our unirrigated lands. The use of covercrops in dry-land farming will in the near future become more of a necessity than it is at the present. It is to be hoped that legumes may be found which will germinate at lower temperatures and will make an appreciable growth during the winter months.

Rate of seeding

The amount of seed required to plant an acre will vary with the size of the seed, the kind of crop, its growth habit, and conditions at the time of planting. The adjoining table gives the rate of seeding which experience has shown is necessary to produce a good stand for most of the crops discussed.

Although the cost of seed is an important item of expense in the growing of a covercrop, it is poor economy to save on seed at the possible expense of a good growth. As stated earlier, the object is to obtain as large an amount of organic matter as possible to turn under. Therefore enough seed should be used to assure a good stand.

When the crop is planted early and conditions for germination and growth are good, the lower rates can be used. When conditions are less favorable—that is, when temperatures are low—rates higher than those indicated may be justified.

In planting a covercrop, especially on preirrigated land, the seed should be drilled in deep enough to contact moist soil. The vetches, peas, and cereals, which all have large seeds, can safely be planted 2 inches or more in depth. The smaller seeded species should ordinarily be planted less deeply. However, when planting is delayed until late in the season, all species should be planted closer to the surface than if they are put in early.

These seeding rates are recommended:

Variety	Amount of seed (pounds per acre)
Vetches	
Common	60 to 75
Purple	50 to 65
Hairy	40 to 50
Calcarata	30 to 50
Monantha	50 to 60
Hungarian	60 to 75
Bitter	35 to 50
Horse bean	125 to 175
Tangier peas	80 to 110
Wedge peas	80 to 110
Field peas	
Canada	75 to 100
Austrian winter	70 to 90
Melilotus indica	15 to 25
Melilotus alba	20 to 30
Fenugreek	35 to 45
Bur clover	20 to 30
Mustards	15 to 20
Cereals	
Wheat	60 to 90
Barley	60 to 90
Oats	60 to 90
Rye	60 to 90

Covercrops should be seeded with a drill (above) to make sure the seed is deep enough to contact moist soil.

Use of a heavy disk harrow (above) to incorporate the covercrop with the soil is better than plowing under.

How to work in a covercrop

The common method of disposing of a covercrop is to plow it under. This, however, is a questionable practice. If the crop is heavy it goes under in a layer which not only retards decay but causes the surface of the soil to dry out.

A better practice, one which is being followed by an increasing number of farmers, is to disk in the crop with a heavy covercrop disk. By this procedure the organic matter is chopped up and incorporated with the soil where it will decay more quickly and completely. Two or three diskings may be necessary to get a heavy crop worked in but, if this is done well, decomposition may progress far enough that a crop can be planted on the land a few weeks after the covercrop has been worked in. If the land is to be planted to a spring crop such as corn, beans or tomatoes, a common practice is first to disk the covercrop to incorporate it with the soil and then to plow. This helps to prepare the seedbed for the following crop.

In orchards the common practice is to disk only enough to kill the growing plants. Complete incorporation with the soil is not necessary and in some cases is held undesirable.

When to work in

The time to work the covercrop into the soil will be determined by the relation to other crops being grown. It should be borne in mind, however, that the greatest benefit will be obtained if the crop is allowed to make as much growth as time and conditions will permit. In many sections of California fall-planted covercrops do not make much growth during the cold winter months.

Not until the days start to lengthen and the seasonal temperatures start to rise will rapid growth really begin. This is usually the latter part of February or early March. During the month of March, if the plants are allowed to grow, they will usually make several times as much actual growth as they have made during the preceding period. If, therefore, a covercrop is worked down early in March, the total organic matter added may be small; if it is permitted to grow until April 1, a good tonnage of organic matter can be obtained.

Of course, it is not possible in all cases to permit the covercrop to grow long enough to secure a heavy growth. In orchards, for example, it must be worked down early enough so that it will not interfere with other orchard practices or compete too strongly with the trees for moisture. If it is to be followed by a spring-planted crop, it must be worked under early enough so that partial decomposition will take place before the succeeding crop is planted. By thoroughly incorporating the organic matter with the soil, and by keeping the soil moist, sufficient decomposition will take place in a few weeks to permit the planting of any crop.

Conditions will vary, and each farmer must follow the practices best suited to his own conditions. It should be kept in mind, however, that the production of a covercrop is a procedure involving considerable expense and that the value of a covercrop is in proportion to the amount of organic matter produced. In all cases, therefore, it should be allowed to grow as long as local conditions and other use of the land permit.

INDEX OF COVERCROPS DISCUSSED IN THIS CIRCULAR

	PAGE		PAGE
Austrian winter pea	15	Horse bean vetch	14
Barley	17	Hubam	16
Bitter vetch	14	Hungarian vetch	14
Black mustard	17	Lathyrus	15
Bur clover	17	Melilotus	16
Calcarata vetch	11	Monantha vetch	14
Canada white pea	15	Mustard	17
Canada yellow pea	15	Purple vetch	10
Cereals	17	Rough pea	16
Common vetch	10	Rye	17
Dixie wonder pea	15	Sour clover	16
Early Austrian pea	15	Tangier pea	15
Fenugreek	16	Trieste mustard	17
Field peas	15	Vetches	9
Hairy vetch	11	Wedge pea	15

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Remember these 12 points about covercrops

1. For most farm lands, covercrops offer the only practical means of supplying the organic matter necessary to keep soil in a high state of productivity. Barnyard and other manures are inadequate to meet the requirements of extensive areas.
2. Fresh organic matter in a process of rapid decay is more effective in improving the physical condition of soil than is the humus residue. High moisture and high temperature favor a rapid rate of decay.
3. Cultivation decreases the amount of organic matter in the soil.
4. As organic matter decays, it provides nutrient elements for succeeding crops. Legumes used as covercrops may substantially increase the nitrogen content of the soil.
5. The value of a covercrop is determined primarily by the amount of organic matter it will add to the soil. Therefore, use the crop which will produce the greatest growth in any particular region or in the time allotted.
6. On light, sandy soils, the fine-stemmed, more succulent species of covercrops—such as vetch or bur clover—will produce the best results. Covercrops producing a stemmy growth with a well-developed taproot—such as mustard—are best for heavy, fine-textured soils such as clay-loam and adobe.
7. Mustard has been found to be most effective in loosening up soil and encouraging water penetration. This is important in orchards.
8. Most covercrops are planted on irrigated land, since early seeding is necessary for a good stand and lack of rain can prevent satisfactory results if irrigation is not possible.
9. Most covercrops should be seeded before the first of November. Preparation of the seedbed is important.
10. It is poor economy to save on covercrop seed at the possible expense of a good growth. Seed should be drilled deeply enough to contact moist soil.
11. The best method of working in a covercrop is use of a heavy covercrop disk. Two or three diskings may be necessary. In orchards, complete incorporation of the covercrop with the soil is not necessary.
12. Allow covercrops to grow as long as possible before working into the soil.